USC Viterbi
School of Engineering

EE599 Fall 2016 Selected Topics

Energy Harvesting Circuits and Systems

Lecturer:
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PHE 620

Lectures:
Tuesday, Thursday, 9:30 am to 10:50 am, KAP 148.

Office Hours (Tentative):
Time: TBA, PHE 620.

Course Summary:
The advances in sensors, embedded processing, and wireless connectivity have fueled the emergence of wearable and implanted electronics. Rather than being carried in a pocket or a bag, these devices actually live on and in us and unobtrusively become part of our daily life. Since the users are always looking for seamless operation of this class of devices, which does not require their intervention to change or charge the battery, energy harvesting from the environment has emerged as a key solution for such systems. This course will provide the students with the solid foundation to design energy harvesting circuits for autonomous systems. The harvesting system consists of three main components (a) energy transducer that converters the energy from its free form in the environment into electrical energy, (b) interface circuits (power converters) that extract energy efficiently from the harvester and deliver it to the load, (c) control circuits for output voltage regulation, maximum power tracking, etc. Thus, the course will also be split into three modules as follows with extensive focus on the interface circuits design:

1. **Power Converters Design:** inductive based converters, switched capacitor DC-DC converters, rectifiers, passives, losses calculation and design strategies for maximal efficiency for ultra low power applications.
2. **ULP Control Circuits:** circuit design in sub-threshold, maximum power extraction techniques, output regulation logic, design of ultra-low power reference circuits.
3. **Fundamentals of Energy Transducers:** equivalent circuits of energy transducers for solar, thermal and vibration based applications.

Grading:

The grading will be based on three components: homework (40%), class participation (10%), class project (50%).

Prerequisite:

This course presumes an understanding of basic circuit theory and MOSFET device physics. The primary course prerequisite is EE348 (or an equivalent course).

Course Outline:

- Week 1: Introduction to self-powered systems and energy harvesting circuits.

Part 1: Power Converters Design

- Week 2: Principles of steady state converter analysis.
- Week 3: Inductive-based converters - continuous conduction mode.
- Week 4: Inductive-based converters - discontinuous conduction mode.
- Week 5: Switched capacitor DC-DC converters design.
- Week 6: Rectifier design, energy methods for calculating losses.
- Week 7: Passives. ***Class project announced***.

Part 2: ULP Control Circuits

- Week 8: MOSEFT in subthreshold - device physics review.
- Week 9: Maximum power extraction techniques, startup circuits.
- Week 10: Pulse frequency modulation and techniques for activity and leakage reduction.
- Week 11: ULP voltage reference and current reference circuits.

Part 3: Fundamentals of Energy Transducers

- Week 12: Equivalent circuits of energy transducers (Part 1).
- Week 13: Equivalent circuits of energy transducers (Part 2).
- Week 14: System examples.
- Week 15: Project discussion.

Required Text Book:

The principle sources for this course will be class handouts and recent papers in the field of energy harvesting and power electronics. The following book is recommended for the first part of the course but not absolutely required: R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, Second edition, Kluwer, 2001.

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism - presenting someone else's ideas as your own, either verbatim or recast in your own words - is a serious academic offense with serious consequences.
Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

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Support Systems

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